

Evaluation Of Carbon Footprint In Southeast Zone Of Surat City

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ABSTRACT

Increased earth's temperature leading to global warming and climate change various anthropogenic activities resulting concentration of GHG. Urban residents and their activities contribute to 85% of global greenhouse gas emissions and especially Carbon dioxide which therefore requires evaluation and monitoring. Carbon footprint is an easy to apply tool for monitoring and evaluating due to various human activities. This paper focuses on the evaluation of Carbon footprint of the southeast zone of Surat city which is renowned as a diamond processing and trading hub in Gujarat, and is rated as the fourth fastest growing city in the world according to a global economic research report. Out of the eight zones of Surat city, the southeast zone was selected as the zone comprises all four sectors:

residential sector, commercial sector, institutional sector and industrial sector. The carbon footprint was calculated according to the intergovernmental panel on climate change 2006 guidelines on greenhouse gas emission especially Carbon dioxide emission, calculated by multiplying activity data with emission factors. Emission factors were developed according to the 2006 IPCC Guidelines. Data were collected considering four parameters namely human factor, electricity consumption, transportation and gas consumption. These data were collected on the basis of bills, personal communications, and questionnaires. Sector wise different human activity contribution to the carbon footprint was considered. The results revealed that, total carbon footprint from the entire selected residential, commercial, institutional and industrial sectors of the Southeast zone of Surat city were 4374023.355 kg CO₂ per day. The Carbon footprint of households was 2256394.79kg CO₂ per day, for commercial buildings was 1650500.585kg CO₂ per day, for institutional buildings was 343048.1 kg CO₂ per day and for selected industrial buildings was 124079.88kg CO₂ per day respectively. Southeast Zone, Surat City

Keywords

Carbon footprint, Greenhouse gases, Carbon dioxide emission, Climate change,

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Introduction

'Climate Change' is one of the most researched areas in the 21st century. To achieve sustainable development limiting the effects of climate change play a very crucial role in worldwide [1]. International policies, planning, schemes, producer and strategies have been aimed at resolving issues to reduce Kyoto greenhouse gases (GHG) especially carbon dioxide (CO₂) that affected climate change [2]. To factors like global warming, ecological issues, economical issues, and ecological imbalance, humidity are related to climate change a world-famous issue. Climate change is the reason for global and local level climate change [3]. Rising population and increase of various industrial activities in the city are transforming it into a source of air pollution and climate issues. Construction of roads and with all day to day activities through increased GHG emissions in to atmosphere.

The intergovernmental panel on climate change is a scientific body was established jointly by the world meteorological organization (WMO) and United nation environment programmed (UNEP) in 1988. To provide scientific view in context to climate change and its potential environmental and socio economic impact, the intergovernmental panel on climate change (IPCC) 2006 for national GHG Inventories provides methodologies for estimating national inventories of emissions by sources and removals of greenhouse gases [4]. As per intergovernmental panel on climate change (IPCC) there are eighteen greenhouse gases, but mainly six gases are considered as

namely: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and sulfur hexafluoride (SF₆) [5]. IPCC report (2018) wise it clear that the world will evidence greater sea level rise, high amount of droughts, floods and heat waves with large populations highly affected of climatic problems.

Surat is an economical capital and coastal city close to Arabian Sea and is located on river Tapi in the southern region of Gujarat.

According to a study conducted by

economic times, Surat will be the world's fastest growing city from 2019 to 2035. It is the eight largest city and ninth largest urban agglomeration of India. Surat is the 34th largest city in the world. Surat was awarded "best city" by the Annual Survey of India's City-Systems (ASICS) in 2013[6]. The word carbon footprint made by three words, carbon addition foot addition print. It is the percept of ecological footprint. Life cycle assessment and ecological footprint both combination of the word carbon footprint. Ecological footprint is the impact of community on the environment, expressed as the land requires sustaining their use of natural resources. Activities like transportation especially use of fossil fuels, industrial processing activities (lifecycle process), farming activities, and other commercial activities etc. In short carbon footprint is a unit, to measure of the frequency of carbon dioxide (CO₂) emissions which caused by all products Assessment. Direct emissions of CO₂ from a burning of fossil fuels along domestic energy consumption,

and vehicular emissions called primary footprint. Indirect CO₂ emissions and whole life cycle process called the secondary footprint. Carbon footprint is the summation of: the primary footprint and the secondary footprint. Primary footprint takes place inside the primary border of the system. It's direct controlled of the system. Secondary footprint takes place outside the border of the system for satisfying the requirement [7, 8]. Calculation of carbon footprint from different sectors as a reference tool and provide better future for global sustainability. Calculation of carbon footprint is also important step towards better carbon management and gaining for carbon credit. In this paper evaluation of carbon footprint of southeast zone of Surat city has been carried out considering IPCC 2006 guideline.

Methodologies

The evaluation of carbon footprint was divided in to 4 steps. As sown in fig. 1, First step consisted of zone selection of Surat for study of carbon footprint. Second step consisted of survey and data collection. Third step consisted of data analysis and fourth step consisted of carbon footprint calculation based on IPCC Guidelines.

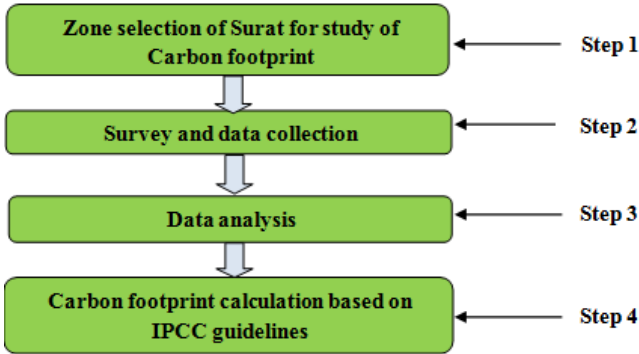


Figure 1: Methodology chart

2.1 Zone selection

Map of Study area, Southeast Zone of Surat city as shown in Figure 2. Total area of Surat City 326.515 km² and is the 2ndlargest city of Gujarat in terms of area and population. The study area was located at 21° 10' 12.8640'' N Latitude and 72° 49' 51.8232'' E Longitude. The city is divided into 8 zones: West Zone, Central Zone, North Zone, East Zone A, East Zone B, South Zone, South West Zone, South East Zone. Southeast zone of the city was selected as included: residential sector, commercial sector, institutional sector, industrial sector and this zone covers 12 Wards of Surat city. Also, Southeast Zone of Surat city is very densely populated with congested buildings and with negligible flora resulting in more carbon emissions. Fig. 2 shows that the study area southeast zone of Surat city. 2.2Survey and data collection Five surveys were carried out include: house hold survey, traffic volume survey, commercial survey, institutional survey and industrial survey. The data was collected through bills, personal communication and questionnaire. The following factors areconsidered as per availability of data in survey period.

2.2.1 Household survey

Survey was carried out in total 12 wards of the southeast zone of the Surat city. 10 sample sizes from each ward were surveyed, with total of (10*12) 120 sample size from household. A questionnaire form as shown in Table 1 was used to determine the total carbon footprint of households.

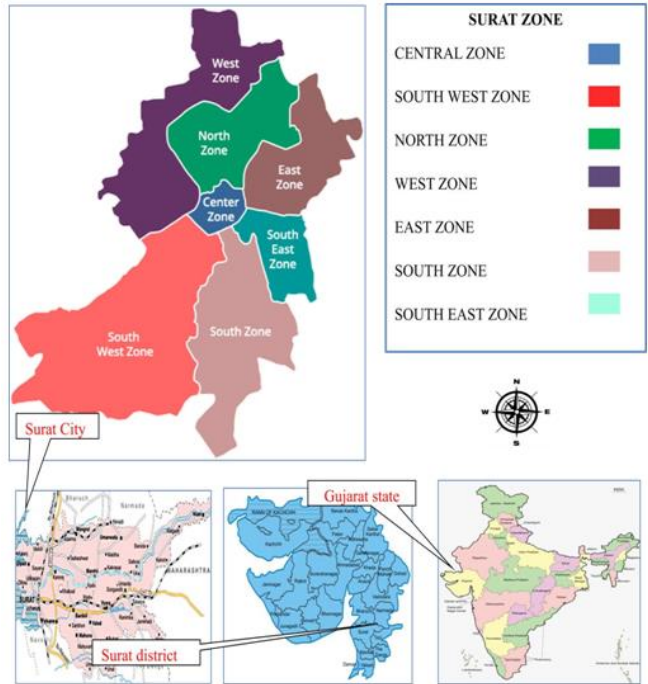


Figure 2: Map of Southeast Zone of Surat City (study area)

Table 1: Questionnaire form for household survey.

1.	Total family member
2.	Monthly electricity consumption (kWh)
3.	Total number of vehicles
4.	Total distance travelled (daily)
5.	Monthly fuel consumption
6.	Amount of Food waste generation
7.	Monthly Gas consumption
8.	Water usage
9.	Solar panel use or not

2.2.1Traffic volume survey Vehicular counting from four different sectors was carried out. For commercial sector total 246110 per day vehicle found household sector 109666 per day vehicle found, institutional sector total 74141 per day vehicle found and industrial sector total

Table 2: Number of vehicles per day in different three sectors of southeast zone

Type of sector	No. of cars	No. of 2-wheelers	No. of rickshaw	No. of buses
Commercial sector	1220	224160	20097	633
Households	6225	89593	13829	19
Institutional sector	2240	60908	10668	325
Industrial building	560	2546	166	98

3370 per day vehicle found. From survey it can be concluded that maximum number of vehicles were found in the commercial sector, and I took a video all day and then counted the vehicles in it. Vehicular activity especially movement of 2-wheeler was found in (commercial sector) the details of which are shown in Table 2.

2.2.2 Institutional survey

Parameters like human factor, electricity

Table 3: Questionnaire form for institutional building

1.	Total number of teaching staff
2.	Total number of non-teaching staff
3.	Total number of students
4.	Monthly electricity consumption (kWh)
5.	Total number of vehicles
6.	Total distance travelled

The institutional buildings are situated in Parvat, Dindoli, and Mithikhadi. Total 12 major institutes were surveyed for Carbon Footprint. It included secondary and higher secondary institutional building. It included consumption; food waste and transportation were considered for evaluating the carbon footprint of educational building. Also, a questionnaire as shown in Table 3 was used for evaluation of details to calculate carbon footprint.

2.2.3 Commercial survey

Surat Municipal Corporation, LIC, Bank, ATM, Sales tax office, shopping mall, complexes and other shops has been selected for evaluating the Carbon footprint of the Commercial sector. Total 18 Commercial buildings are covered in calculation of carbon footprint, situated in Parvat, Magob road, Navagam, dindoli of the southeast zone. The movement of private vehicles and other vehicles are more in selected commercial area. For evaluating carbon footprint of commercial building, three parameters namely human factor, electricity consumption and transportation were considered as per availability of the data. Also, a questionnaire as shown in Table 4 was used for details to calculate carbon footprint.

Table 4: Questionnaire form for commercial building.

1.	Total number of persons
2.	Total number of vehicles
3.	Which type of vehicle used
4.	How many Electrical appliances used?
5.	Distance travelled (Daily)
6.	Which type of fuel used

2.2.4 Industrial survey

The Carbon Footprint of 13 Industry (company) of the southeast zone. Textile Mill, Elastic industry, Chemical suppliers, polymer, plastic manufacture these types of company involved in southeast zone of Surat city. This type small industry has been selected for evaluating the Carbon Footprint of industrial survey. For evaluating carbon footprint of industry, three Parameter Human Factor, Transportation, Electricity was considered as per availability of data. And this all questionnaire through collected data help to calculate the carbon emission in different sectors. As shown in Table 5 this data's details help to evaluation of carbon footprint.

Table 5: Questionnaire form for industrial building.

1.	Total number of persons
2.	How many technical and nontechnical person
3.	How many electrical appliances used?
4.	Which types of electrical appliances
5.	Electricity used?
6.	Which types of transportation they prefer?
7.	Labour persons use bicycle?
8.	Daily travelled (details)

2.2.5 Data collection

In the present study as shown in Table 6 all data were gathered door to door interview, personal communications and questionnaire form through. A total 120 households, 13 industrial building (company), 18 commercial building and 12 institutional building were included in southeast zone of Surat city. This all data were analyzed and help to suggest step for reduction of carbon footprint. So analysis and after evaluation of carbon footprint in southeast zone of Surat city.

Table 6: Parameter and source of data [9]

Characteristics	Parameters of data	Source
Electricity	Electricity consumption kWh	Bills
Transportation (By own vehicle)	Fuel consumption Distance travelled(Daily) Type of vehicles Type of fuel No. of days per week	Personal communication Questionnaire
Gas	Gas consumption MMBtu	Bills
Human Factor	No. Of persons	Personal communication Questionnaire
Food waste	Food waste generation	Personal communication Questionnaire

2.3 Data analysis

As per collection of data and different sectors survey analyse transportation factor is highest contributor in atmosphere. As well as their carbon footprint is highest amount as compare to human factor, electricity consumption, and food waste, gas consumption. In residential and commercial sector is hub in carbon hotspots, because that sector consisted of human factor and human use more private vehicles as compared to public transport vehicles. So vehicular emission is high, therefore this both sector's carbon footprint amount is highest as compared to institutional and industrial sector. In general industrial sector create high pollution, and emit high amount in carbon dioxide (carbon footprint) but in this sector small level manufacturing industries were available. In this industrial building mainly non- technical labour is working. Also they prefer a bicycle as a transportation factor, and this labour were localized. So automatically vehicular emission is reduced and carbon footprint is less as compared to other three factors. Figure 3 shows that Total carbon footprint of transportation factor in all four sector. Commercial sector is highest 59.01%, second highest residential sector is 27.41%, third highest institutional sector is 12.22% and least industrial sector is 1.34% respectively.

2.4 Calculation of carbon footprint

The carbon footprint equivalent emission factor was used to find the carbon footprint from each activity. Questionnaire through collected data change in to proper unit as per emission factors guidelines. According to IPCC (2006) guidelines, greenhouse gas emissions (GHG) especially Carbon dioxide emissions can be calculated by using following formula [6, 8].

$$\text{GHG} = \text{A.D} \times \text{E.F}$$

Where, A.D = Activity data

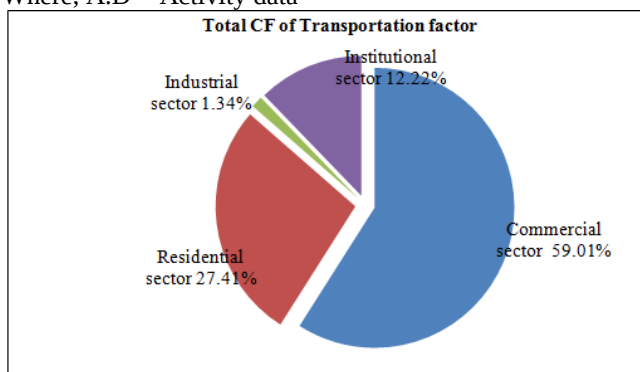


Figure 3: Total carbon footprint of transportation of all sectors

E.F = Emission factor A value of emission factor is obtained from the IPCC (2006) guidelines and emission factor of electricity consumption of Gujarat is obtained from GHG inventory report for electricity generation and consumption in India [10]. Table 7 shows that the various Emission inventory and their emission factors for calculating GHG especially carbon footprint. This emission factors are as per IPCC guidelines [4].

Table 7: Emission inventory and their emission factors

Sr. No.	Emission inventory	Emission Factor (EF)
1	Human factor	1.14 kg CO ₂ per day
2	Electricity consumption	0.73 kg CO ₂ per kWh
3	Solid waste generation	0.125 kg CO ₂ per kg
4	Cars	0.23 kg CO ₂ per km
5	2-wheeler	0.14 kg CO ₂ per km
6	Bus	0.13 kg CO ₂ per km
7	Chakra/ 3 wheeler auto	0.15 kg CO ₂ per km
	rickshaw	
8	Gas consumption	53.06 MMBtu

Results And Discussion

3.1 Carbon footprint of households The Carbon footprint of total households of southeast zone was 2256394.79 kg CO₂ per day. Total carbon footprint of human factor, electricity consumption, gas consumption and transportation contribute were 566580 kg CO₂ per day, 536063.93 kg CO₂ per day, 416438.86 kg CO₂ per day and 737312 kg CO₂ per day respectively. These factors are considered as per availability of data. This zone is mainly slum area; they not separate dry and wet waste, and data are not proper manner. Therefore food consumption is not considered in household sector.

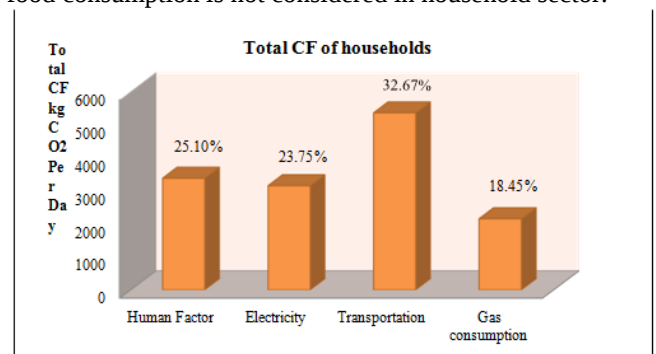


Figure 4: Total carbon footprint of household

Figure 4 shows the total carbon emissions of the household. The overall result revealed that the carbon footprint of transportation in residential area of the southeast zone (direct emission) is higher 32.67% than other factors. Because that area having more Vehicular activity (private vehicles) so that The overall carbon footprint (carbon dioxide emission) of the transportation is higher than other considered factors. While second highest, human factor is 25.10% third electricity consumption is 23.75% and least factor gas consumption is 18.45% respectively.

3.2 Carbon footprint of commercial sector The overall result shows that the total carbon footprint of commercial Sectors situated in Parvat, Magob, Umarawada and Limbayat. The total carbon footprint of selected commercial buildings was 1650500.585 kg CO₂ per day. Carbon footprint of human factor, electricity consumption and transportation were 6982.775 kg CO₂ per day, 55618.81 kg CO₂ per day and 1587899 kg CO₂ per day respectively.

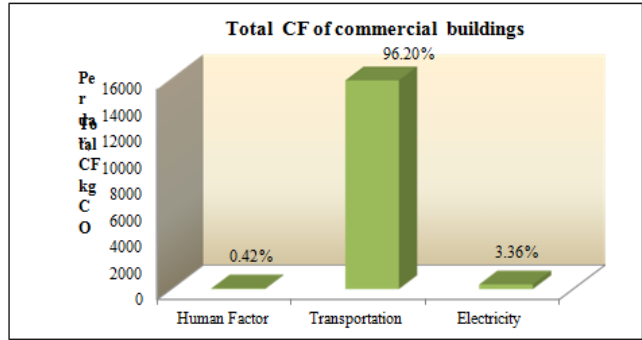


Figure 5: Total carbon footprint of commercial buildings

Figure 5 shows the total carbon emissions of the commercial buildings. The results revealed that the carbon footprint of transportation (direct emission) is higher 96.20% than other factors, because vehicular activity is more in Parvat, limbayat.

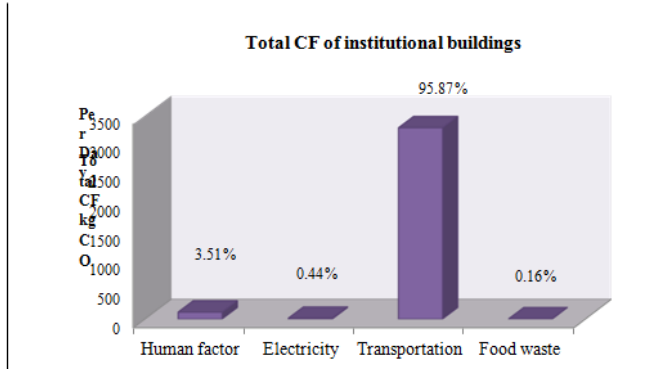
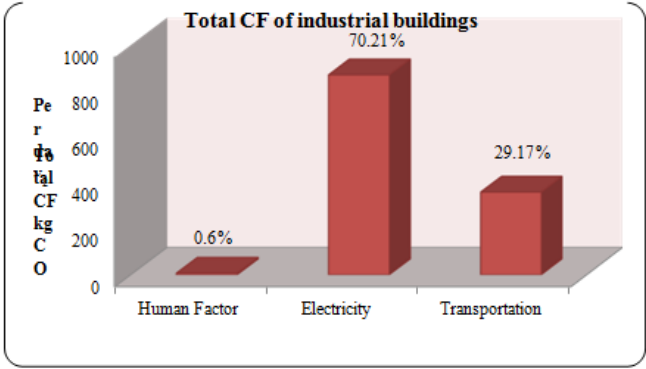


Figure 6: Total carbon footprint of institutional buildings

Movement of private vehicles is more than movement of public transport vehicles (buses, chakra, and auto-rickshaw). Where second highest, electricity consumption is 3.36% and least human factor is 0.42% respectively.

3.3 Carbon footprint of institutional sector

Carbon footprint of transportation was 328906 kg CO₂ per day, while carbon footprint of human factor, electricity consumption and food waste were 12067.9 kg CO₂ per day, 1518.52 kg CO₂ per day and 555.68 kg CO₂ per day respectively. The Total Carbon Footprint of Institutional building was 343048.1 kg CO₂ per day. Figure 6 shows the total carbon emissions of the institutional buildings. Result revealed that the carbon footprint of transportation (direct emission) is higher 95.87% than other factors. Human factor represents the second largest portion 3.51% of the total emission. While carbon footprint of electricity consumption and food waste generation is 0.44%, 0.16% respectively.



3.4 Carbon footprint of industrial sector The overall result shows that the total carbon footprint of small level industry likes elastic industry, polymer manufacture and suppliers, chemical manufacture and suppliers. The total carbon footprint of selected industry was 124079.88 kg CO₂ per day. Carbon footprint of human factor, electricity consumption and transportation were 766.08 kg CO₂ per day, 87118.2 kg

CO₂ per day and 36195.6 kg CO₂ per day respectively

Table 8: Sector Wise Total Carbon footprint

Types of Sector	Total CFP (kg CO ₂ per day)
Household	2256394.79 kg CO ₂ per day
Commercial	1650500.585 kg CO ₂ per day
Institutional	343048.1 kg CO ₂ per day
Industry	124079.88 kg CO ₂ per day
Total CF = 4374023.355 kg CO ₂ per day	

Figure 7 shows the total carbon emissions of the industrial buildings. Result revealed that the carbon footprint of electricity consumption is higher 70.21% than other considered factors. Transportation represents the second largest portion 29.17% of the total emission.

While human factor represents 0.6% respectively. In industry production equipment, machines usage are high amount in day to night time therefore electricity is high compare to transportation factor and this sector mostly labor is working and they use bicycles, so automatically vehicular emission is reduce. In industrial sector generally create high carbon footprint but in this zone limited small scale manufacturing company were available, therefore industrial sector create less carbon footprint as compare to other considered sector.

Table 8 represents the overall Carbon footprint of Commercial buildings, institutional buildings, households and industry of Southeast zone of Surat city were 1650500.585, 343048.1, 2256394.79, 124079.88 kg CO₂ per day. While Figure 8 shows the Total percentage wise carbon footprint of Commercial sector contributes (37.73%), while institutional sector (7.84%), holds (51.58%) contribute and industrial sector contributes (2.83%) to the atmosphere.

Transportation accounts high carbon emission, because vehicular activity is more at that commercial area. Movement of 2-wheelers, Chakra and Auto-rickshaw in that area is more than movement of public transport vehicles (Buses).

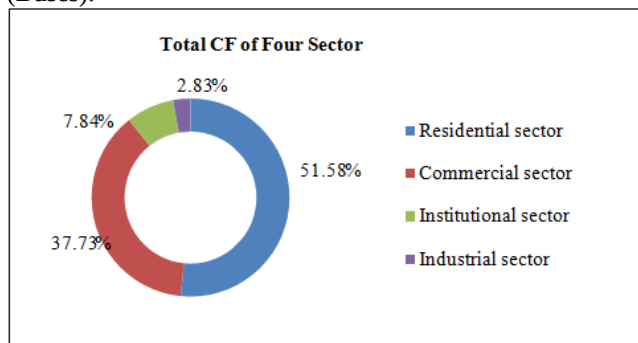


Figure 8: Total CF of All sectors in percentage

Conclusion

Among all the factors transportation is the biggest contributor to the residential, commercial and institutional sector whereas in the industrial sector, electricity is the major contributor to the carbon footprint.

Long distance travel and high percentage of personal vehicle usage in the commercial and residential sector result in much higher carbon footprint as compared to institutional and industrial sector. Usually industry contributes to higher carbon emission but in this sector small scale limited manufacturing industries were available therefore, carbon emission is less as compared to other three sectors. The overall results revealed that total carbon footprint of institutional sector, commercial sector, residential and industry of southeast zone were estimated to be 4374023.355kg CO₂ per day (4374.02335 tonnes CO₂ per day). The carbon footprint of institutional sector 343048.1 kg CO₂ per day (7.84%), commercial sector 1650500.585 kg CO₂ per day (37.73%), Residential sector 2256394.79 kg CO₂ per day (51.58%) and industrial sector 124079.88 kg CO₂ per day (2.83%) respectively. In All the sector residential sector is the highest contributor of air pollution, we observed that pandemic of COVID – 19 shutdown during big reduction in air pollution and air quality index was up (satisfactory) in Surat city. It is suggestion step towards making sustainable city, in the world many countries should shut down a week like this every year, so automatically carbon content (carbon footprint) reduction and improvements in air quality. These carbon emissions in South east zone as well as all zones of Surat city can to be reduced substantially by various mitigation methods such as adopting US policy of school selection in the areas of living, strictly using mass transport facilities like BRTS, avoiding wastage of electricity, transportation create higher carbon emission, so as per world health organization (WHO) suggest transportation is avoided in lock down period due to pandemic of COVID – 19, use of solar panels for energy and their by supporting Indian Government initiative and incentives for solar use, adopting efficient ways of cooking in villages which leads to reduced burning of wood, industries can have their emission control using well maintained equipment's as well as pollution control.

COVID - 19 global pandemic has changed the Air quality index in Surat city and across the world but the learnt lessons have to be kept intact.

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